Investigation of spectroscopic properties and laser oscillation of oxides ceramics manufactured with SHS-MS method

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Introduction

Nizhny Novgorod:

- *Institute of Chemistry of High-Purity Substances* stands for preparation of nano-powders
- *Institute of Applied Physics* stands for baking and samples benchmarking

Y_2O_3 SHS technique from acetate nitrates complexes

Self-propagating high-temperature synthesis (SHS) means the synthesis of compounds (or materials) in a wave of chemical reaction (combustion) that propagates over starting reactive mixture owing to layer-by-layer heat transfer

Metal acetate nitrates were prepared by dissolving oxides in an aqueous solution of acetic and nitric acids:

$$1/2Y_2O_3 + 3x\ HNO_3 + 3(1\text{-}x)\ CH_3COOH \longrightarrow Y(NO_3)_{3x}(CH_3COO)_{3(1-x)}\ aq$$

SHS precursor

Reaction propagation

High-disperse oxide

Gyrotron-based system for materials processing

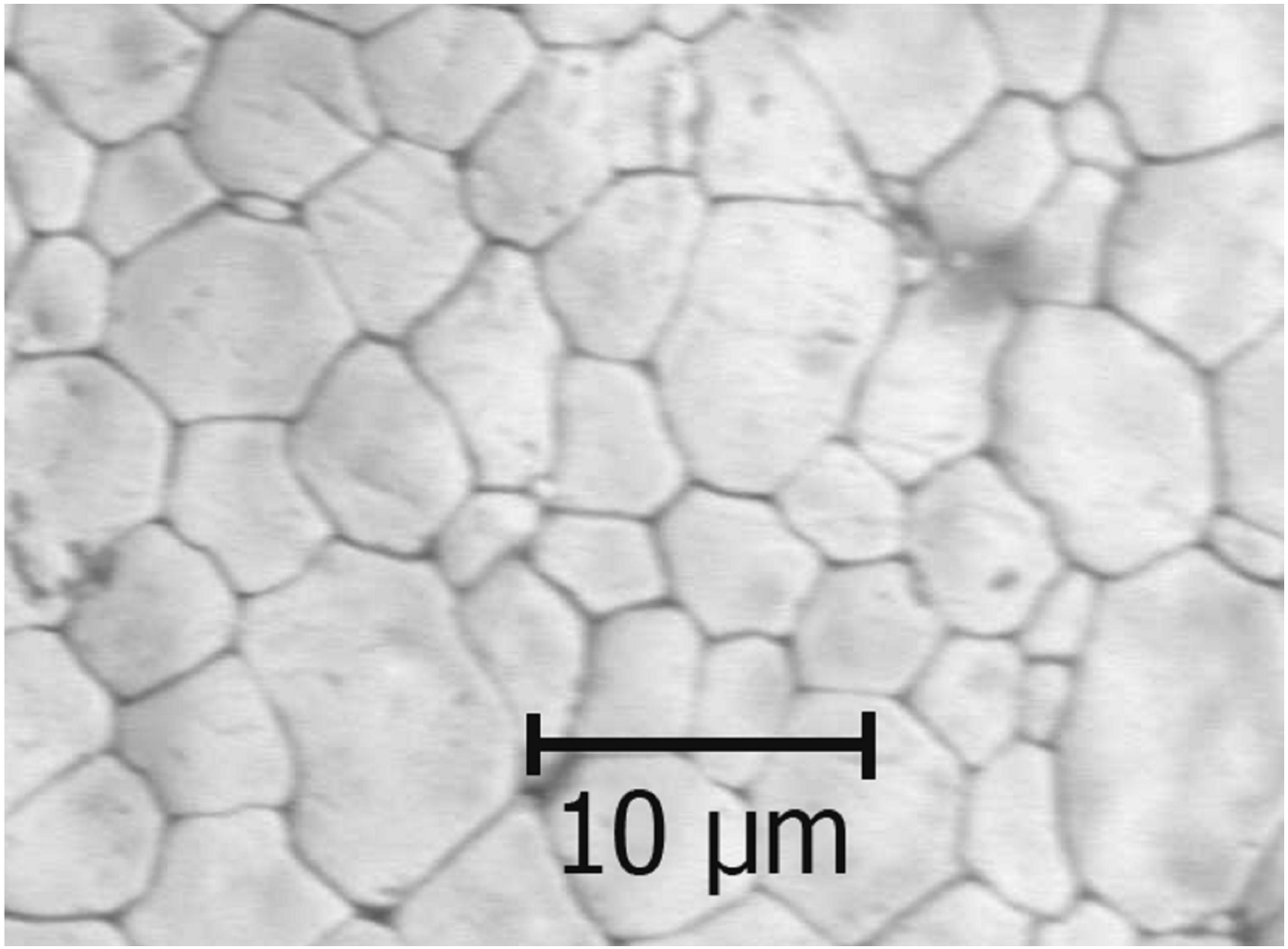
Utilization of microwave heating is promising due to absence of resistive heating elements which can contaminate material at high temperatures. The additional advantage of this method is its less energy consumption compared to conventional sintering

6 kW 24 GHz gyrotron system

Impurity composition of powders was investigated using atomic emission spectrometry with inductively coupled plasma (AES-ICP) iCAP 6300 (USA) and revealed no significant differences in impurity composition of both starting powders (see table 2) and sintered ceramics.

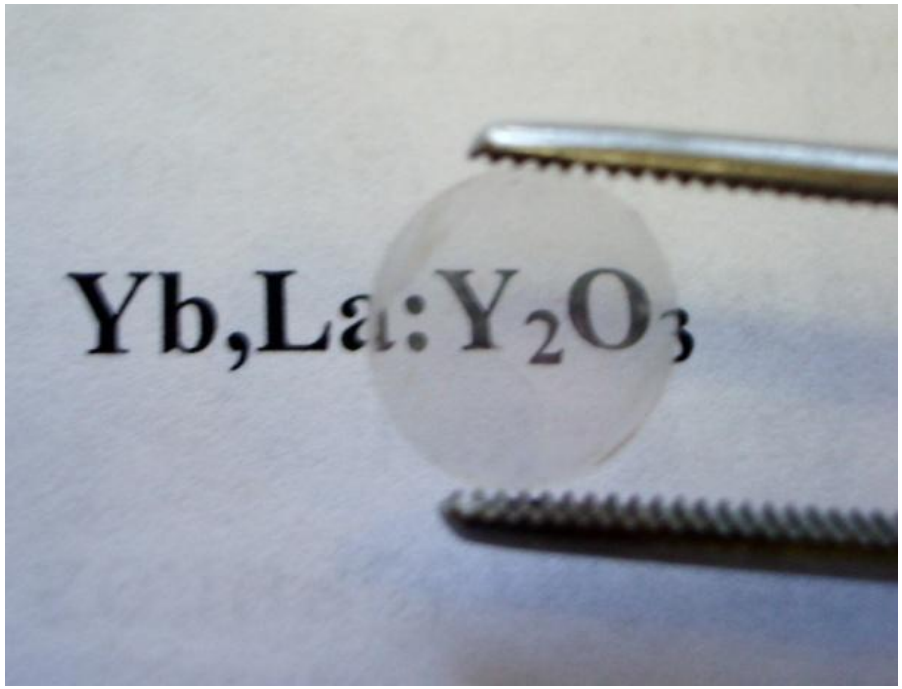
Ceramics

Scanning electron microscopy of baked Yb:Y_2O_3 ceramics

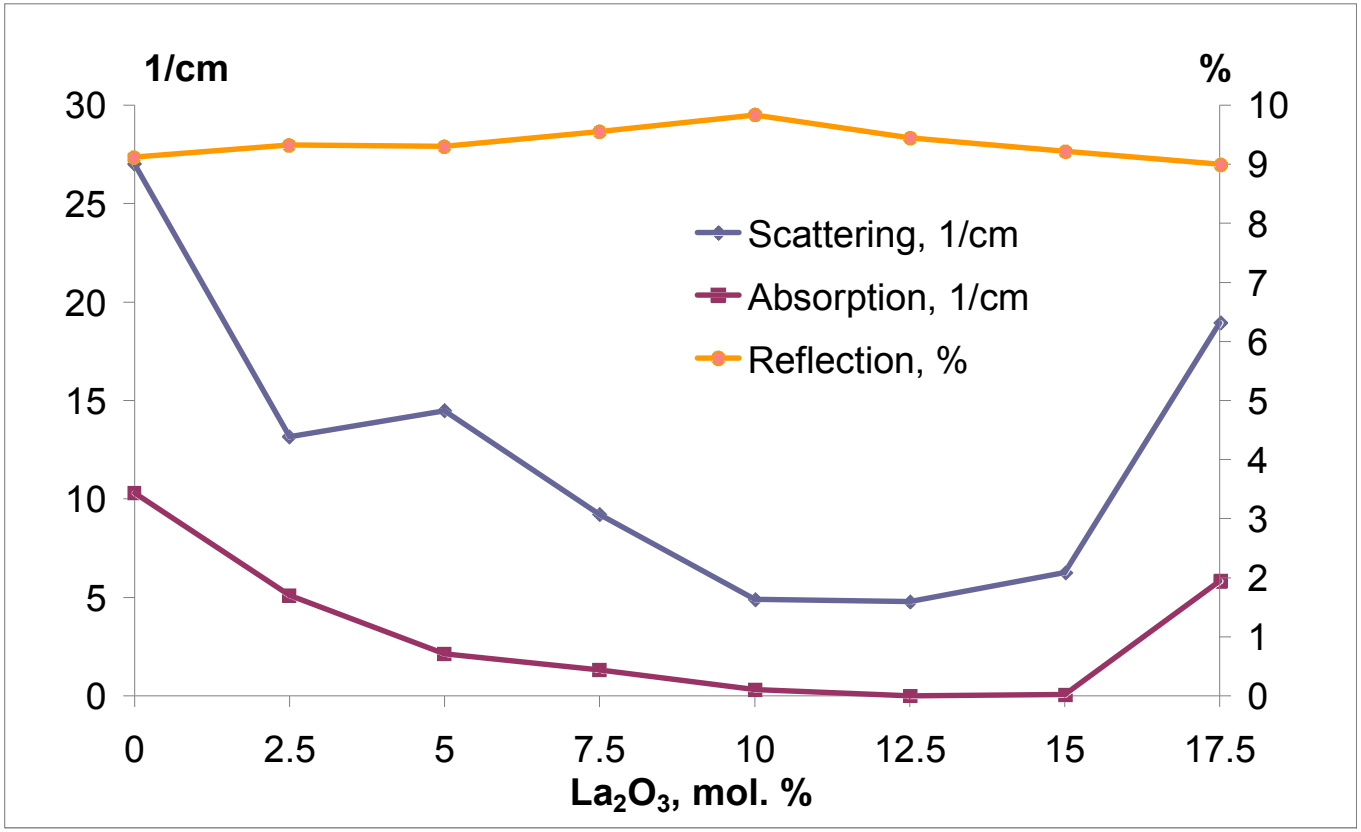


Lanthanum

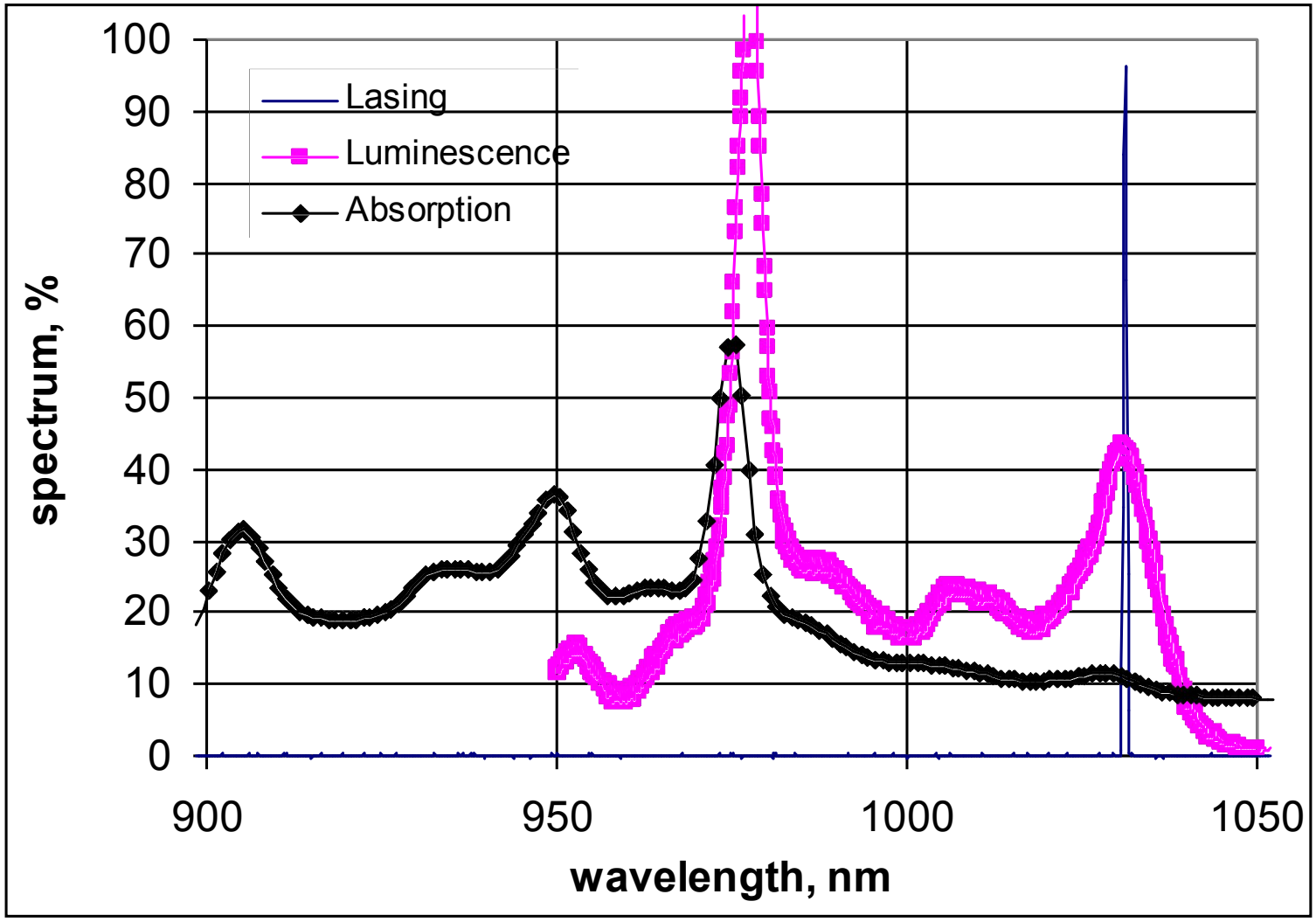
To produce a highly transparent material during sintering several additives are often used, such as ZrO2, La2O3, Gd2O3 and others. We are using lanthanum oxide.



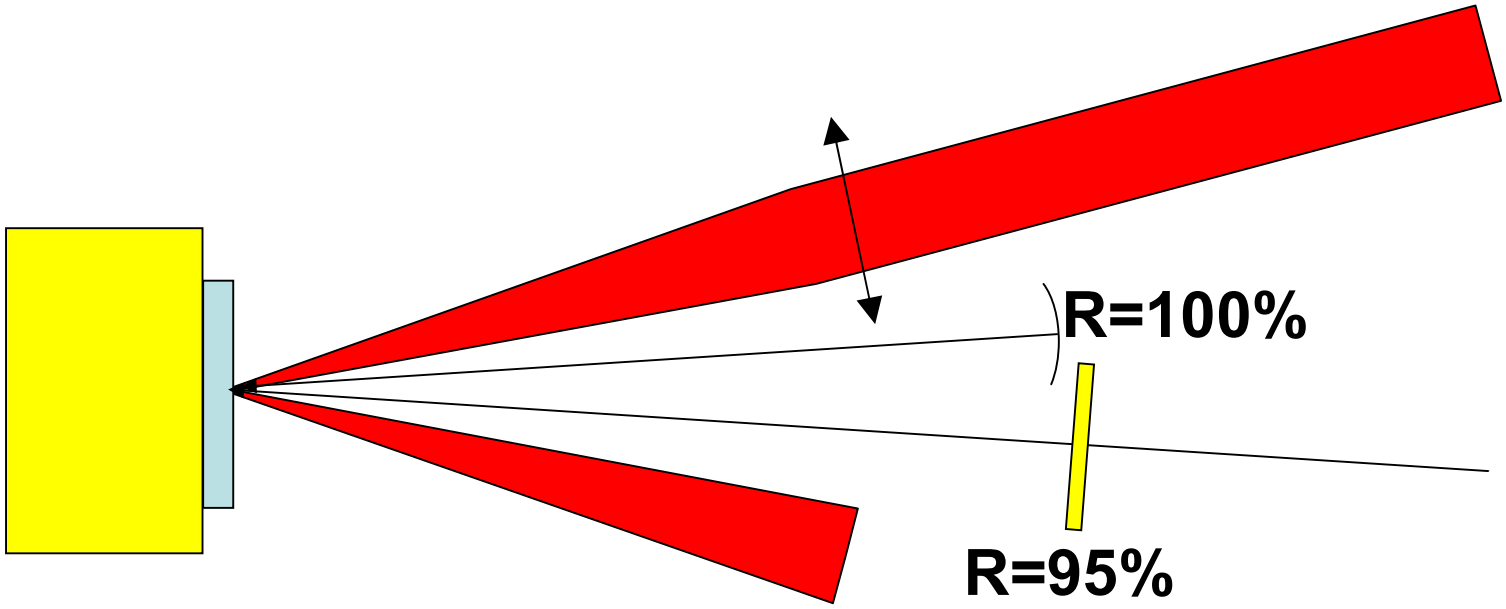
Selecting the best Lantanium concentration



Absorption and Luminescence spectrums

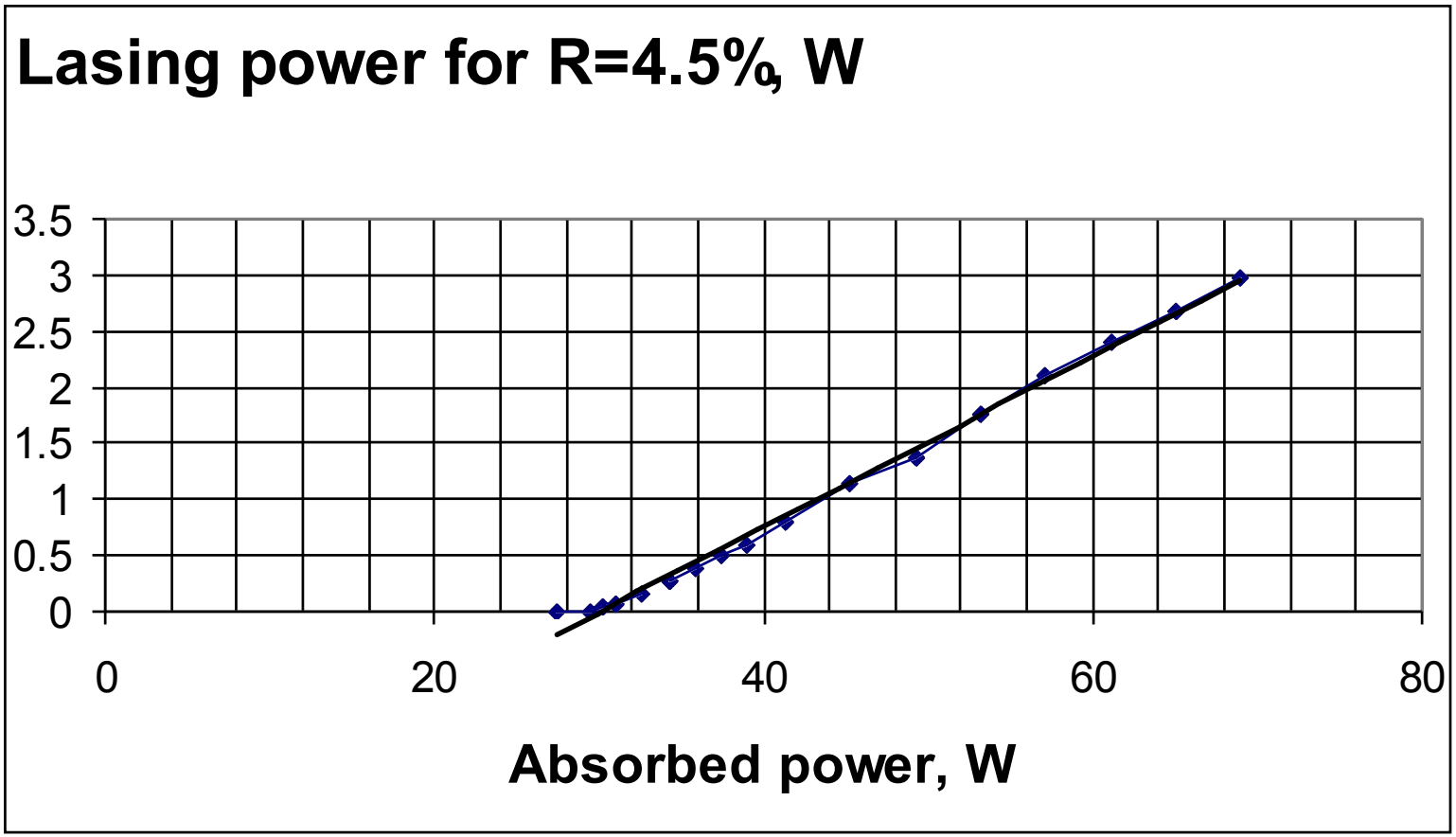


Lasing experiment



Lasing results

Best slope efficiency was **8%**
(for 4.5% transmission of output mirror)



Cooling

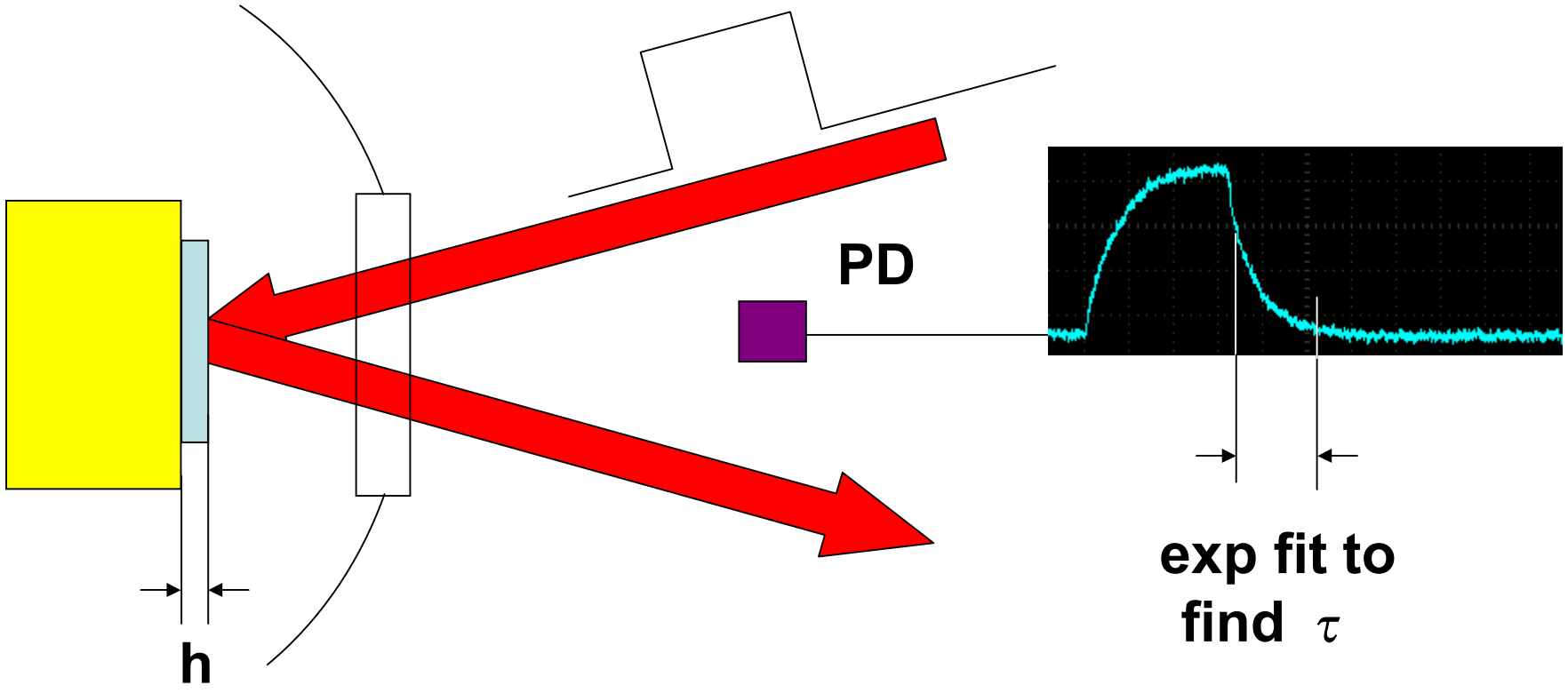
$\frac{dn}{dT}$ ↓ **~10 times**

æ ↑ **several times**

$\frac{dl}{dT}$ ↓ **~ 5 times**

α_{las} ↓

Measurement of Lifetime



Broadening the set of investigated materials

Yb-doped ceramics:

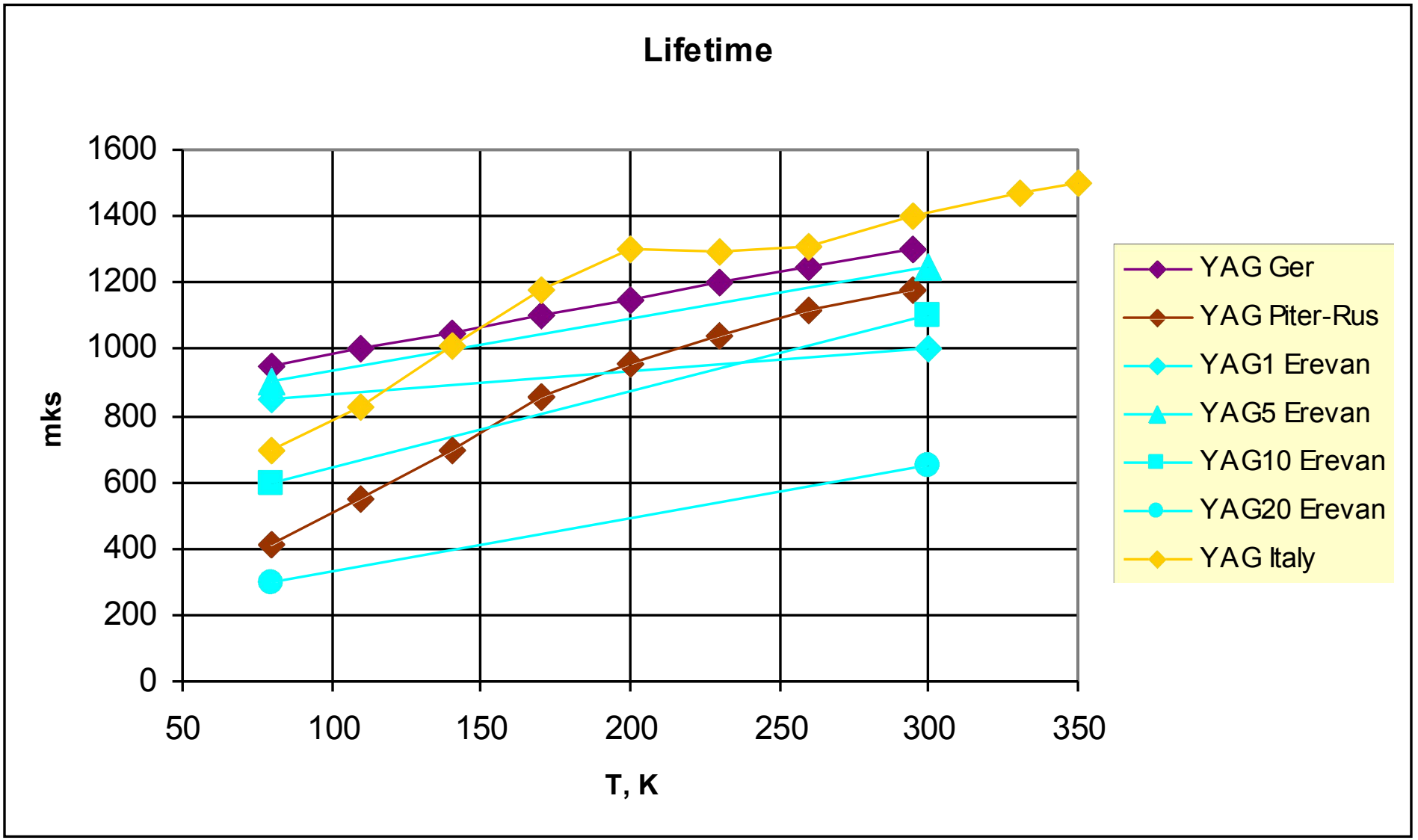
Y_2O_3 **- Japan** (provided by Prof. Kaminsky)
2% Yb
Sc_2O_3 **- Japan** (provided by Prof. Kaminsky)
2% Yb
Lu_2O_3 **- Japan** (provided by Prof. Kaminsky)
2% Yb
Y_2O_3 **– Nizhny Novgorod, Russia**
5% Yb

Broadening the set of investigated materials

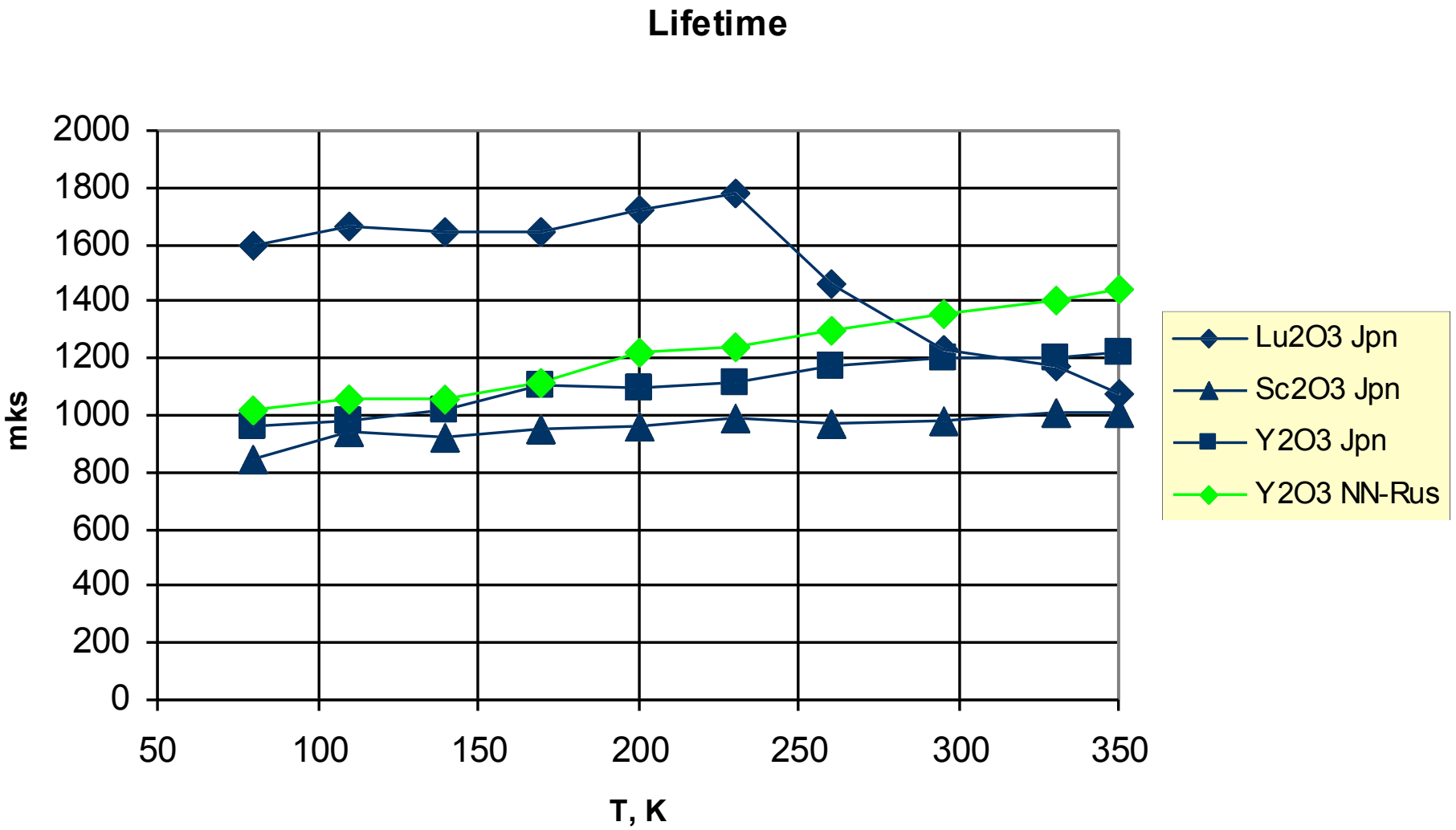
Yb-doped crystals:

YAG **- Germany** (provided by Moltech Gmbh)
10% Yb
YAG **- St.-Peterburg, Russia**, (Vavilov Institute)
10% Yb
YAG - **Italy**
1% Yb
YAG **- Erevan**, **Armenia** (Laserayin Tekhnika CSC)
1-20% Yb (5 samples)

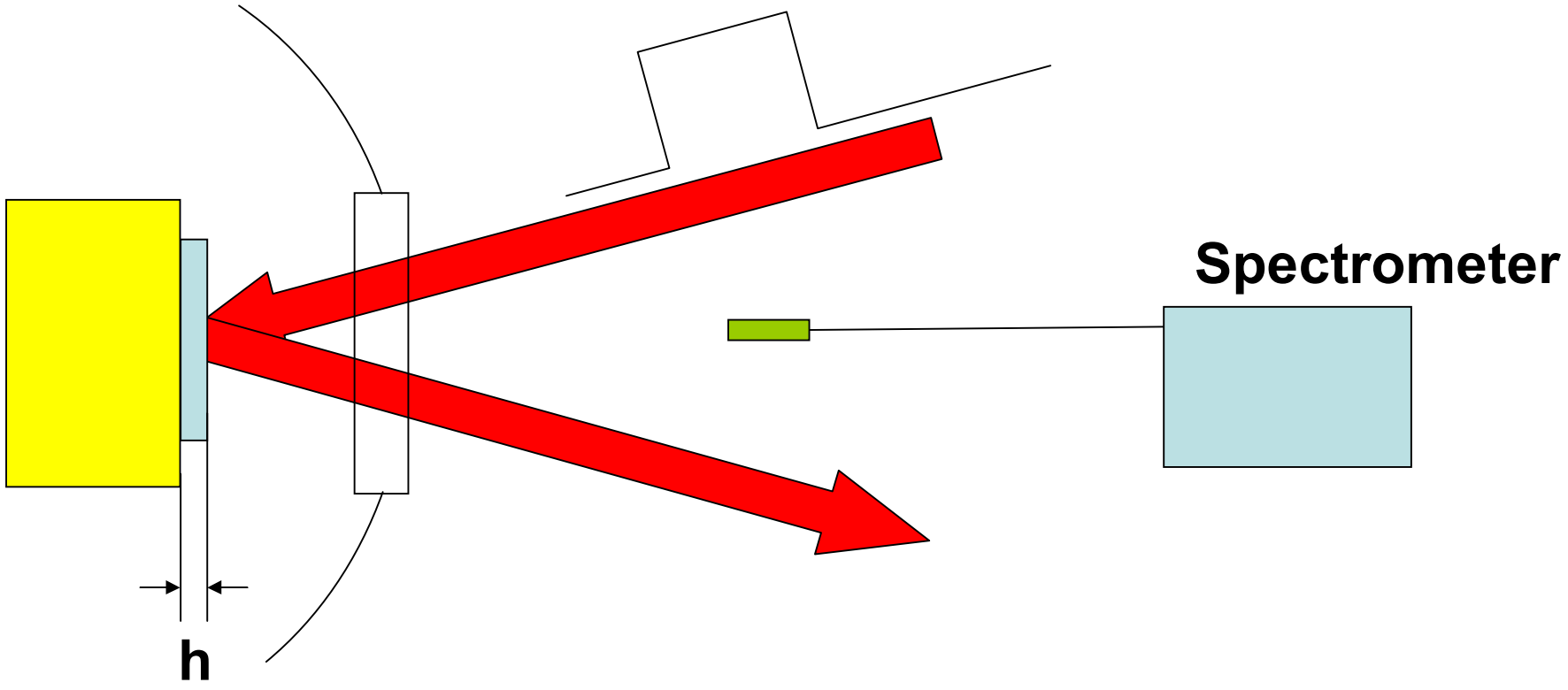
Lifetime measurements



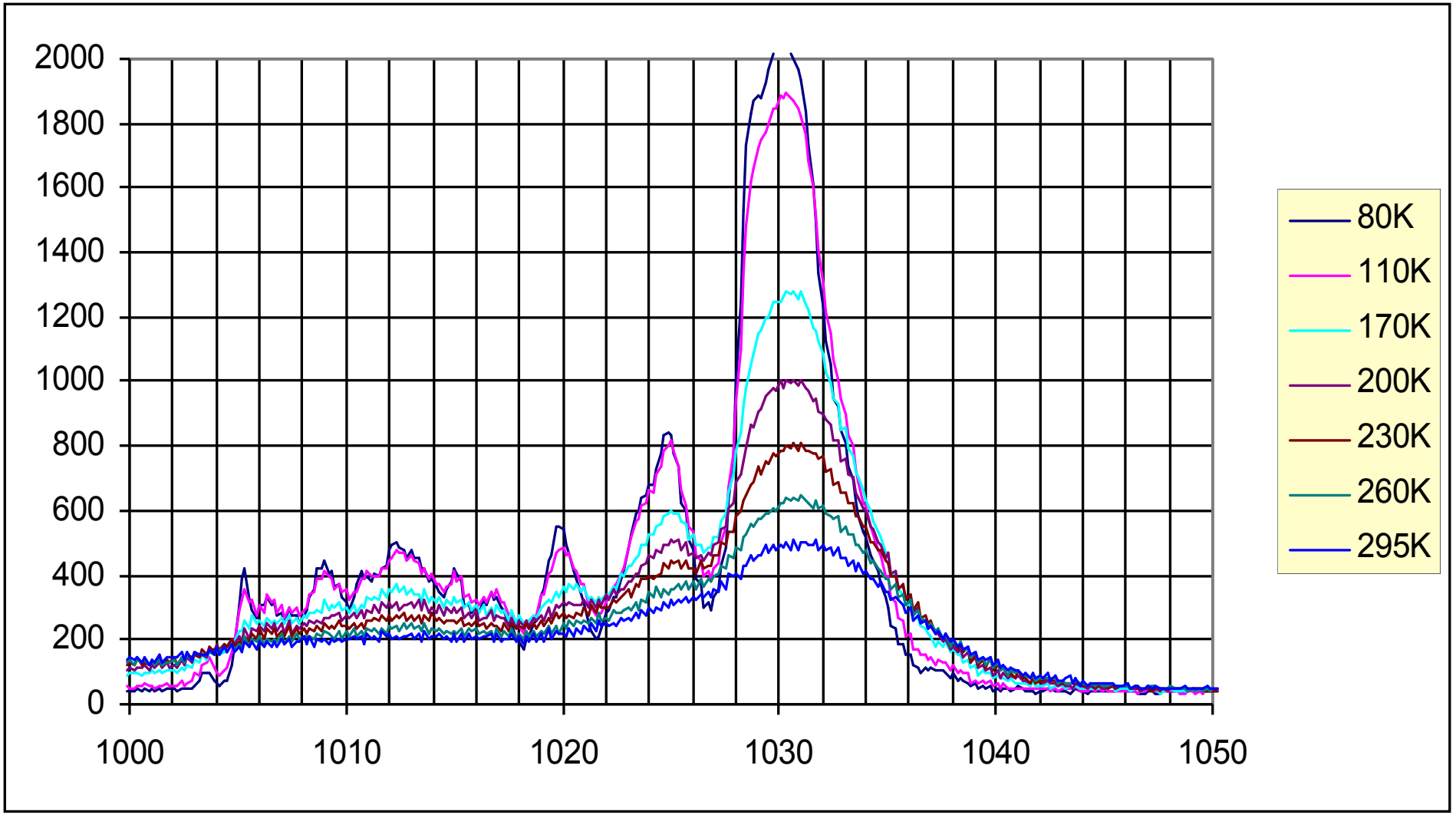
Lifetime measurements2



Measurement of Luminiscence



Luminescence spectrum measurements



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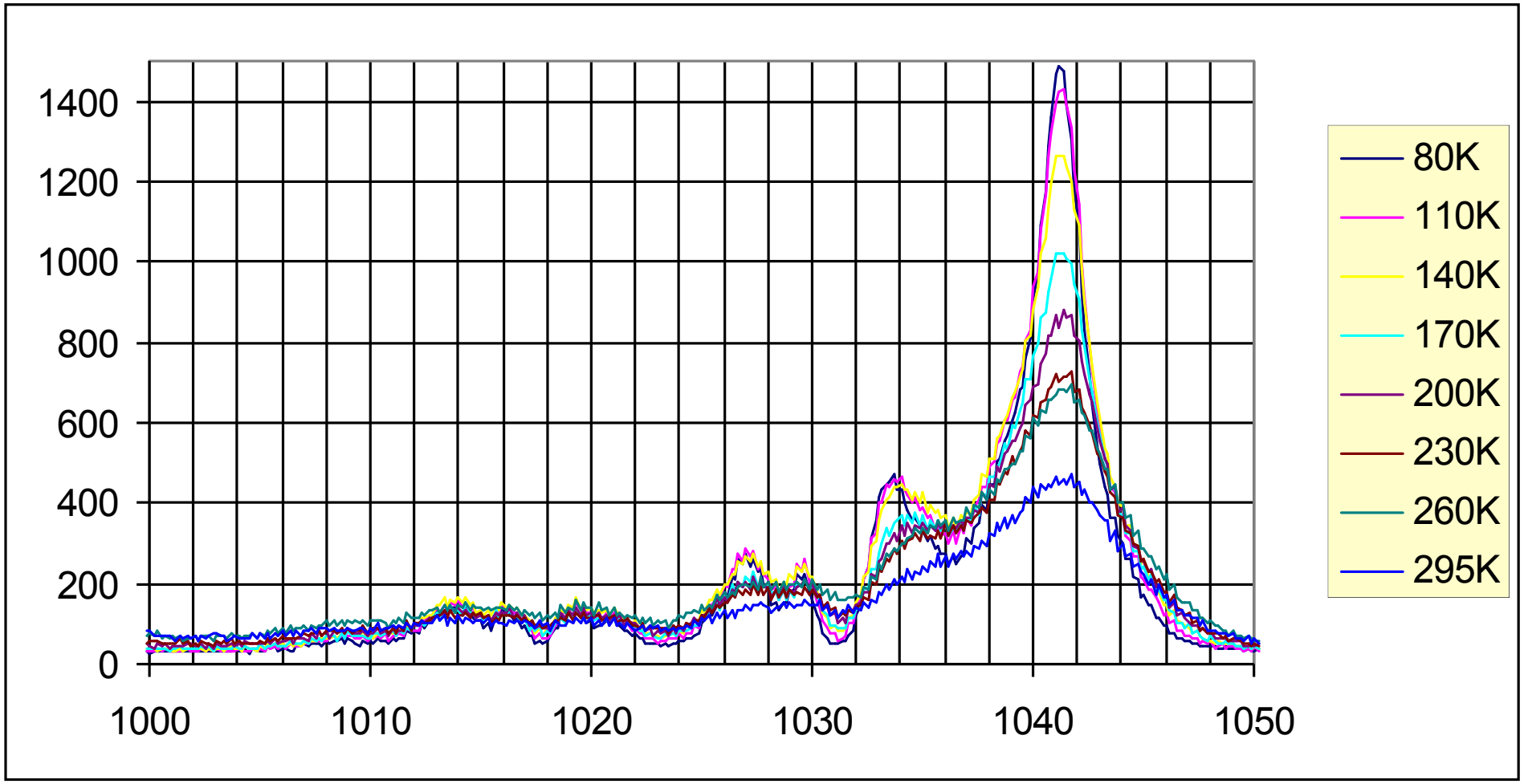

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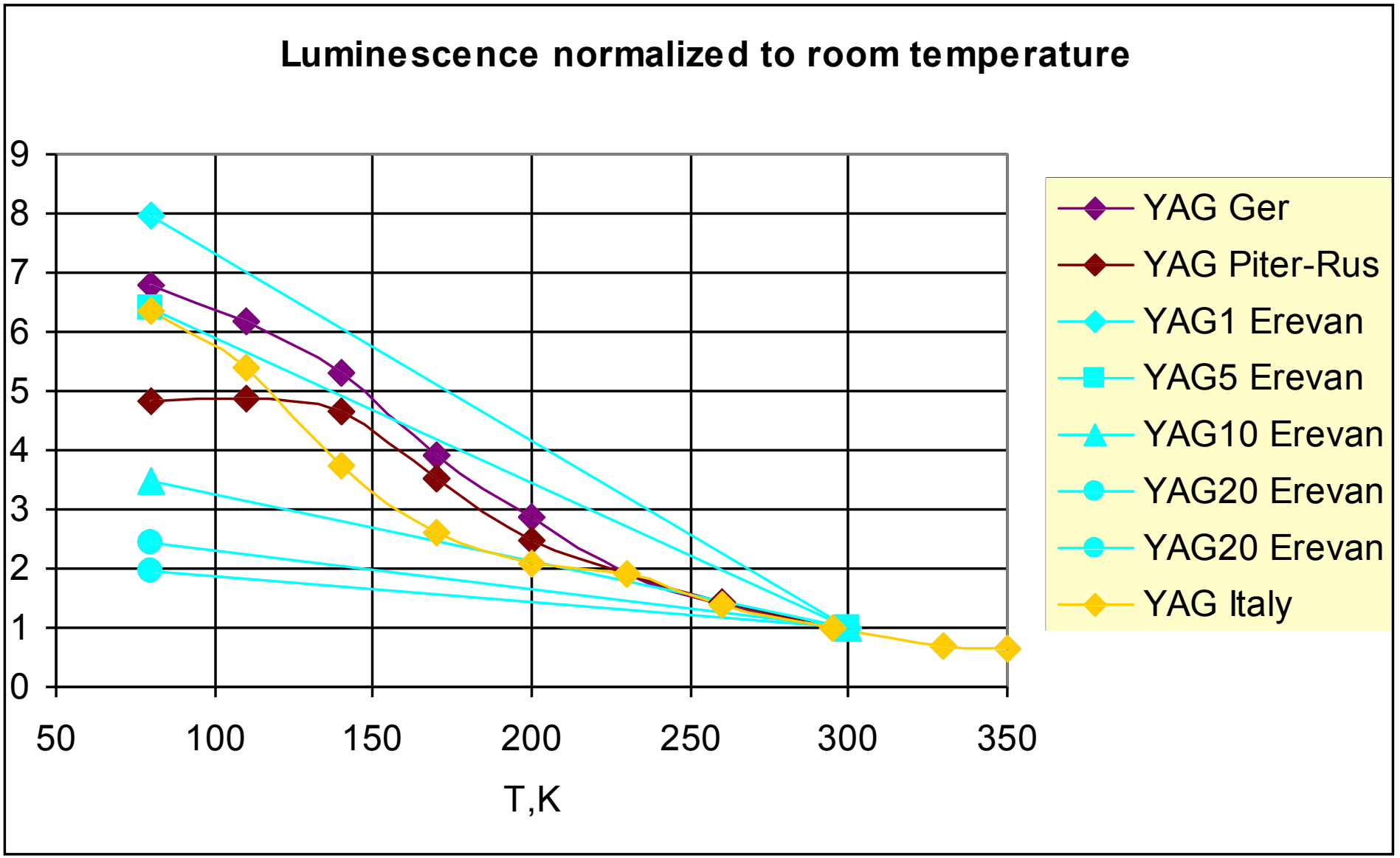
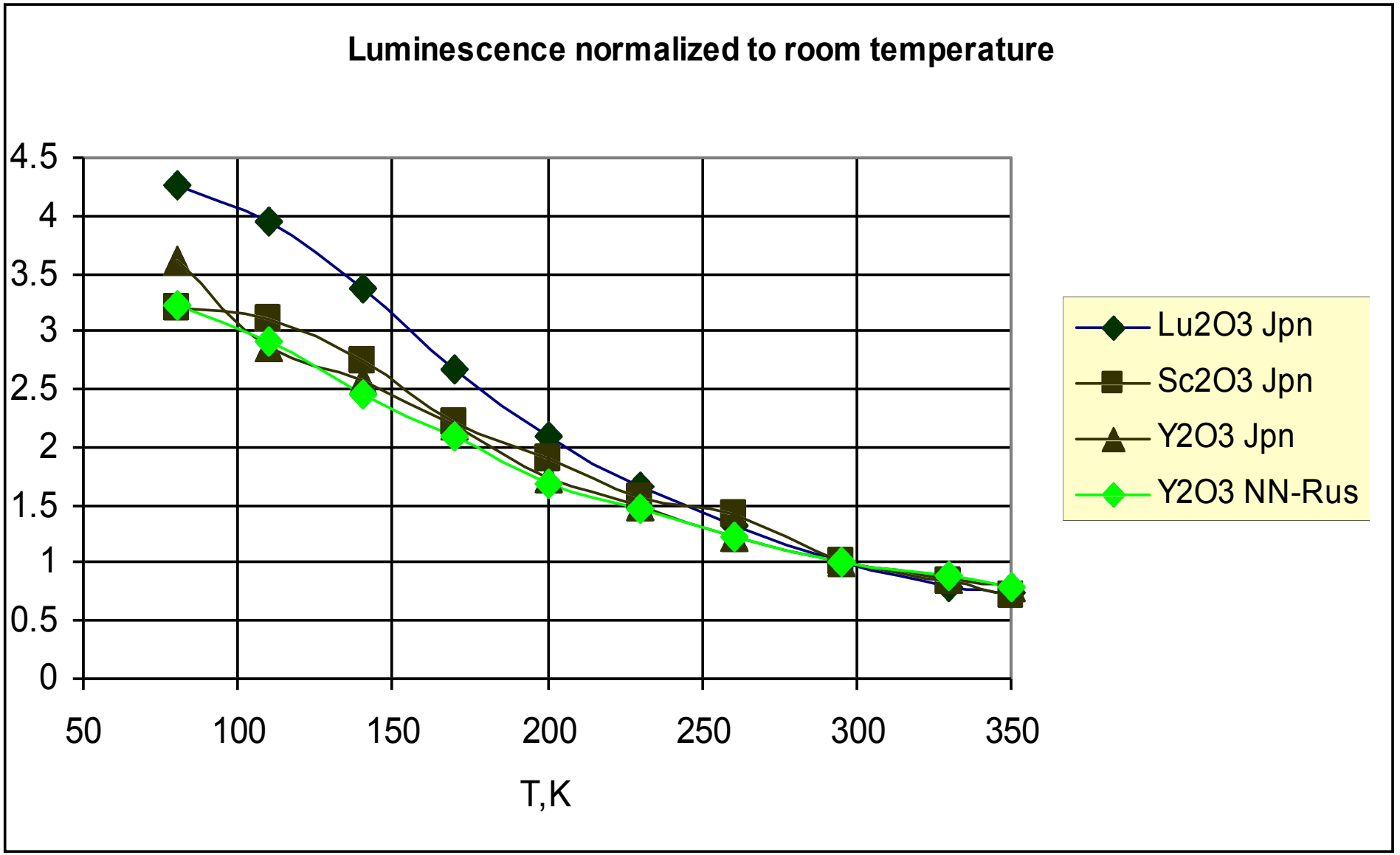
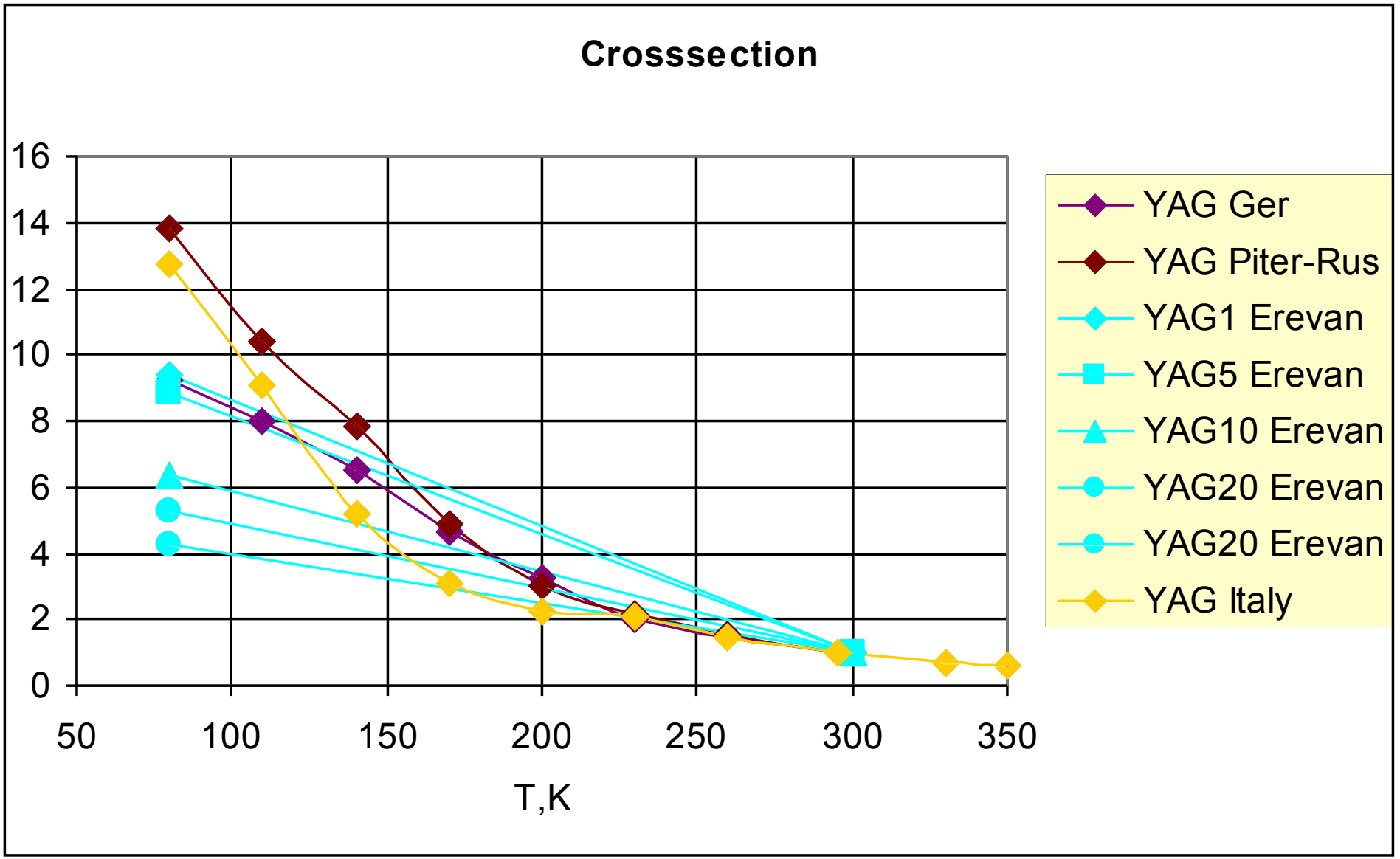


Luminescence spectrum measurements



Emission cross section



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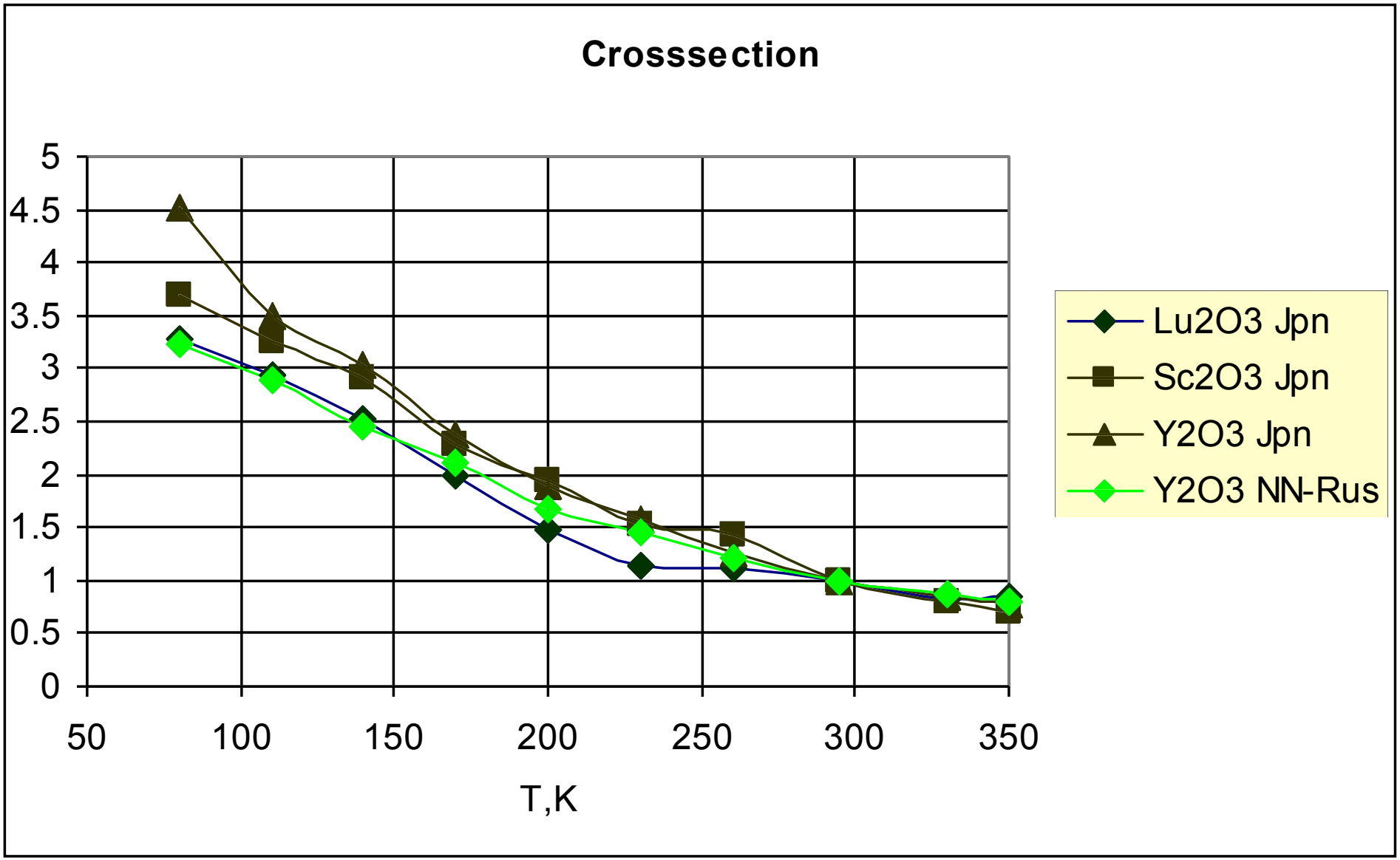

Results

- Ceramics manufacturing method was developed in Nizhny Novgorod. Optical quality was demonstrated to be high enough to get 8% of slope efficiency
- Wide set of optical ceramics and crystals was tested and there were measured lifetime and cross section change while cooling down to 80K
- Wide spread in parameters behaviour observed for YAG crystals
- It was measured 3.5 increase in cross section for ocsides ceramics and decrease of lifetime from 1.1 ms down to 0.9 ms and it was observed similar behavior for SHS-MS manufactured ceramics
- Measured 3.2 increase of cross section and growth of lifetime from 1.1 ms up to 1.6 ms makes Yb:Lu_2O_3 ceramics quite promising for diode pumped high energy capacity systems
- Measured luminescence spectrums of ceramics showed about several nm spectrum widths at 80K which makes this ceramics promising for amplification of sub-picosecond pulses.